ASSESSING URANIUM CONCENTRATION IN DRINKING WATER: CASE-STUDY IN PAVLODAR REGION, KAZAKHSTAN

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ОЦЕНКА СОДЕРЖАНИЯ УРАНА В ПИТЬЕВОЙ ВОДЕ: ИССЛЕДОВАНИЕ В ПАВЛОДАРСКОЙ ОБЛАСТИ, КАЗАХСТАН

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This paper presents research results on uranium in drinking water in the territory of the Pavlodar region. Research data shows that uranium content in water is significantly higher than its maximum permissible concentration of 0.015 mg/dm^3 as stated in the acts, which Russia and the USA has approved by the PEL of 32 µg/l. Two out of five settlements where uranium concentration in water is at its peak suffer from anthropogenic impact. The results show that water in the northeastern part of the investigated area contains high uranium level due to geological and metallogenic peculiarities of the region.

Introduction. Use of poor-quality drinking water leads to deterioration of human health, thus decreases natural resistance of an organism, and causes early functional changes in various physiological systems. Thus, the body's response to environmental pollution manifested in the form of diseases of cardiovascular system, skin, digestive organs, miscarriage [4]. It has particularly strong impact on children health [3]. Many researchers have identified statistically significant links between drinking water quality and endocrine disorders, neoplasms, anemia, respiratory diseases, congenital anomalies in development of the circulatory system in the result of medical-geographical assessment [5, 11]. Paper examines other researches in the field of drinking water with uranium in Pavlodar region. Currently Kazakhstan is studying organoleptic properties of water, content of main macroions and microelements in water, radiation status of borehole waters, isotopes of radioactive elements more or less in detail, but there is not any research devoted to uranium in water and its toxic properties [9, 12].

Radioelement migration depends on the form of its content in natural waters. Thus, uranium dissolved in water is dangerous mostly because of its high chemical toxicity and to a lesser degree of its radiotoxicity [7]. Since uranium has toxic effect on kidneys, it is often called "kidney poison" [8]. Researches [2] have shown that there are organs that accumulate this radioelement, i. e. liver, heart, spleen, and lungs. Uranium tends to accumulate in trophic links of food chain and is therefore of particular danger to vital activity of living organisms. Level of uranium in water depends on its depth. Moreover, flow of uranium into the upper and lower layers is different. In the former case, precipitation and surface sources, altered by anthropogenic factors, can cause impact. In the latter case, uranium is spread from enclosing rocks. Besides uranium level in water depends on its mineralization, dissolved substances, permeability of rocks, and status of environment in general.

Methodology materials and methods

Research Territory Description. In hydrogeological terms Pavlodar region is located within the Irtysh artesian basin of the second order (II). The Irtysh artesian basin is a part of a large West Siberian basin of the first order (I). The rest of the region occupies the northern slopes of the Central Kazakhstan hillocky area (Kokshetau – Ekibastuz hydrogeological region of the second order (II)). Regional water resources consist of surface runoff from the River Irtysh, some smaller rivers, i. e. Shiderty, Olenta, Seleti and etc., and groundwater. Major operational reserves of fresh groundwater are concentrated to sediments of the cretaceous, to a lesser extent, to the complexes and horizons of the paleogene, neogene and quaternary ages of the Irtysh artesian basin [10].

Metallogenic zoning of uranium assumes that this territory is a potential uranium-bearing complex with both natural and anthropogenic objects. Natural objects include iron-titanium-zirconium deposits that border some regions (Akmolinskaya) with various ore occurrences and brown coal basins, which make a radioecological hazard. In addition, part of the territory is represented by a mountain system with access to the surface of bedrock (granites, granosyenites). High concentrations of radionuclides are often confined to saline lake deeps (Karasor, Zhamantuz). Anthropogenic objects with high radioactivity include former long-term active Semipalatinsk nuclear test site, 39 % of which belongs to Pavlodar region. Research about uranium level in drinking water of Pavlodar was included the following districts: Irtyshsky, Aksusky, Aktogajsky, Pavlodarsky, Zhelezinsky, Lebjazhensky, Bajanaul'sky, Majsky, Jekibastuzsky, Uspensky, Shherbaktinsky (figure 1). Study involved not only rural but urban territories as well, i.e. Pavlodar City and Aksu City.

Figure 1. Drinking water sampling map (Pavlodar region, Kazhakstan)

1. Aktogaysky district; 2. Bayanaulsky district; 3. Zhelezinsky district; 4. Irtyshsky district; 5. Terenkol district; 6. Akkulinsky (Lebyazhensky) district; 7. Maysky district; 8. Pavlodarsky district; 9. Uspensky district; 10. Shcherbakty district; 11. Aksu municipal government; 12 Ekibastuz municipal government

Number of factors has affected a choice of sampling points: climate, landscape, morphology, anthropogenic pollution sources, previous research and regulatory documents. The other important factor is fair distance from the territory of the former Semipalatinsk nuclear test site, which is on the border of three regions East Kazakhstan, Karaganda and Pavlodar. In addition to the main factors, we have tried to take sampling evenly on the area of Pavlodar region.

Sampling Method. Drinking water is sampled according to GOST R 51593-2000 [6]. In Pavlodar City drinking water was sampled mainly from the tap in well-maintained apartments by draining water for about 2–3 minutes. Since we have tried to determine uranium content in drinking water, sampling was kept in containers made of polymer materials that are allowed to contact with water. Before sampling, the containers were rinsed with water at least twice and filled to the top. Since it was not possible to transport water samples to the laboratory immediately, before closing the container with a plug, the upper layer of water was drained so that there was a layer of air under the plug and it was not wetted during transportation. In order to be able to examine the water for a month, the samples were canned with concentrated nitric acid at a rate of 7 cm^3 per 1 dm^3. Each sample volume is 0.5 liters; the number of samples is 20. Some people in Pavlodar live in the houses that use water from the columns along the streets. Number of samples is 8.

Aksu is a relatively small town. Its territory has been divided through «envelope» method. Water samples were taken both in the city center and on the outskirts. 6 samples were selected in total, two in well-maintained houses, and rest of the samples in columns. In Ekibastuz City, 5 samples of water were taken from both the apartments and from the columns. These three cities have a number of townships and together with them are known as city administrations of Pavlodar (41 samples), Aksu (10 samples), and Ekibastuz (12 samples).

In rural settlements drinking water was sampled from individual wells, stand-pipes or drill holes. The depth of the wells ranged from 6 to 20 meters. 95 % of the total number of water samples is from wells. The depth of the drill holes, which constitute a small number of water samples, was 200–600 m. 2 to 5 water samples were taken in outskirts and central parts of the villages, i. e. 6 to 14 samples in each district.

136 samples of drinking water were collected from 11 districts of Pavlodar region, during the month, delivered to the research laboratory for microelement analysis in International Innovation Research and Educational Center "Uranium Geology" of the Department of Geoecology and Geochemistry of Tomsk Polytechnic University and investigated on a spectrophotometer "Fluorate-02-2M" (Method M 01-15-2010). The filter fluorimeter "Fluorate-02-2M" is a device equipped with light filters, a cuvette, a standard sample and specific reagents. In our research we have used a 10 • 10 mm cuvette. Method of measuring intensity of delayed fluorescence of uranyl ions ($\lambda = 530$ nm) in the moment when it is excited by ultraviolet radiation is used to determine uranium concentration in solutions. To enhance luminescence, sodium polysilicate (pH 8.10) is added to the solution. The limits of the relative error of measurements with observations $n = 2$, i. e. 2 weighed quantities were analyzed from each sample of drinking water. Arithmetic mean value is resultant value of these two measurements. Have gotten results on uranium level in water, authors took additional water samples from places, where its uranium value significantly exceeded arithmetic average of the entire sample. However, additional sampling confirmed previous results.

Data Analysis and Discussion. Analytical data on uranium level in water is presented in Table 1.

It is possible to distinguish three groups of rural districts based on uranium level in drinking water. In the first group, metal level in water exceeds 20 μg/l. Pavlodarsky (51.4), Uspensky (36.8 μg/l) and Lebyazhensky

Table 1. Statistics of uranium distribution in drinking water (administrative districts of Pavlodar region, mkg/l)

Районы Districts	X ± SE / min … max	σ	Me	Mo	V, %
Pavlodar municipal government	51.4 ± 22.2 / 4.6 … 327.5	82.9	28.9	n/d	161.4
Uspenskydistrict	36.8 ± 11.9 / 24.9 … 48.7	16.8	36.8	n/d	45.7
Lebyazhensky district	22.7 ± 11 / 4.1 … 106.7	33.02	8.2	n/d	145
Aksu municipal government	12.9 ± 1.2 / 9.5 … 14.7	2.3	13.7	n/d	18
Maysky district	12.1 ± 2.4 / 3.1 … 25.2	8.1	11.8	n/d	67
Ekibastuz municipal government	11.8 ± 1 / 6.6 … 16.1	3.5	12.4	15.1	30
Aktogaysky district	11.5 ± 1.1 / 7.1 … 14.8	2.9	11.8	n/d	25
Bayanaulskydistrict	10.4 ± 1.2 / 4.8 … 20.5	4.4	9.5	n/d	42
Irtyshsky district	10.3 ± 1.3 / 0.4 … 31.9	10.7	6.6	n/d	104
Shcherbakty district	8.1 ± 2.4 / 0.4 … 24.2	7.8	5.3	n/d	96
Zhelezinsky district	7.7 ± 0.9 / 6.3 … 12	2.2	7	n/d	28
Total	**17.7 ± 3.4 / 0.4 … 327.5**	**34.8**	**10.9**	**6.6**	**196**

X – arithmetic mean, SE – standard error, σ – standard deviation, Me – median, Mo – mode, Min – minimum, Max – maximum, V – coefficient of variation; n/d – no data.

(22.7 µg/l) districts belong to this group. Uranium level in water in the second group, the most numerous one, is around 10–20 µg/l. In the third group of districts, element level is less than 10 µg/l. The lowest level in drinking water is noticed in Zhelezinsky district (7.7 µg/l). Taking into account standard deviation and arithmetic mean, we calculated coefficient of variation, which varies widely from 25 to 276. Then we divided districts according to this indicator into three groups: 1). V to 50 % – Uspensky, Ekibastuzsky, Aktogaysky, Aksusky, Zhelezinsky, Bayanaulsky; 2) V from 50 to 100 % – Shcherbakty, Maysky; 3) V more than 100 % – Irtyshsky, Pavlodarsky, Lebyazhensky districts. Most of the districts belong to the group with V value till 50 %, which, despite anomalous concentrations of the element in drinking water, indicates its homogeneous distribution in the research territory.

Laser-luminescent analysis has shown that average concentration of uranium in water of settlements is 17.7 µg/l for 135 samples with a range from 7.7 to 51.4. These high indicators exceed maximum permissible concentrations in Russia (0.015 mg/dm^3) and USA (0.032 mg/dm^3) (figure 2). It means that when uranium level in water is 17.7 µg/l, its average concentration in scale is between 30–40 mg/kg. Maximum uranium level in water of Pavlodar region is in Naberezhnoye village (436.2 mg/kg).

Thus, we determined areas with high uranium level in water, which are mainly located on the right bank of Pavlodar region. It was mentioned above that we deter-

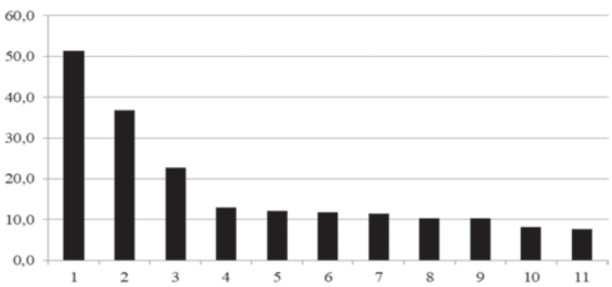

Figure 2. Distribution of rural districts of Pavlodar region in terms of uranium level in drinking water

Abscissa axis: settlements (1 – Pavlodar municipal government, 2 – Uspensky district, 3 – Lebyazhensky district, 4 – Aksu municipal government, 5 – Maysky district, 6 – Ekibastuz municipal government, 7 – Aktogaysky district, 8 – Bayanaulsky district, 9 – Irtyshsky district, 10 – Shcherbakty district, 11 – Zhelezinsky district); ordinate axis: value, µg/l.

mined uranium level in drinking water not only in villages, but also within the boundaries of cities, in which it turned out to be significantly less high, i. e. 7.4 times than in Pavlodar city, 2.7 times than in Aksu city. Drinking water in settlements is supplied through centralized sources (water intakes), and in private sectors through wells and drill holes. Primary entry of the element into water in private sectors depends on geological and metallogenic features of the territory, which is not the same for urban areas. It should be noted that cities are supplied from surface water source, i. e. the main River Irtysh, and in Aksu, uranium excess is higher 2 times. Comparison of analytical data with literature sources showed that in Pavlodar region uranium level in drinking water (17.7 μg/l) is 3 times higher than in the River Tuim (Khakassia) and 23.3 times than in basins of Tomsk Rivers. The smallest uranium level is observed in the water of the eastern slope of the Kuznetsk Alatau (0.38 μg/l). At the same time, uranium level in water of the south of Western Siberia is associated with enclosing rocks [1].

Conclusion. Quality of drinking water is factored by a set of indicators. This paper analyzes geochemical features of uranium, nature of its distribution, connection with its formations and degree of impact on human health. Research results conclude that more thorough further research on uranium in Pavlodar region shall take place, as it is not only a sign of drinking water quality, but ecological and geochemical status in general, as well as possible deposits and ore occurrences.

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RADIOACTIVE POTENTIALITY OF ALKALI FELDSPAR GRANITES OF HOMRET EL GERGAB AREA, EASTERN DESERT, EGYPT

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In terms of natural radioactivity, it is well known, for instance, that igneous rocks of granitic composition are strongly enriched in Th and U (on an average 15 μg g^{-1} of Th and 5 μg g^{-1} of U), compared to rocks of basaltic or ultramafic composition (< 1 μg g^{-1} of U) .For that reason, higher radiation levels are associated with igneous rocks and lower levels with sedimentary rocks. There are exceptions, however, as some shales and phosphate